DAMAGING HYDROGEOLOGICAL EVENTS (DHEs) IN CALABRIA (ITALY)

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CNR-IRPI Cosenza
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DAMAGING HYDROGEOLOGICAL EVENTS (DHE)

Predisposing factors
Geological and geomorphological framework

Triggering factors
Severe weather conditions (heavy/ prolonged rainfall and strong winds)

DAMAGING HYDROGEOLOGICAL EVENTS
Occurrence of damaging phenomena as landslides, flooding, and storm surges

Direct damage: victims, injured, structures and goods destruction

Indirect damage: economic loss due to destruction of roads and services
THE STUDY AREA: CALABRIA REGION (Italy)

Area: **15,230 km²**
Mean altitude: **418 m a.s.l.**
Maximum altitude: **2266 m a.s.l.**
Population density: **133 inh/km²**
Mean annual rainfall: **1151 mm**
GEOLOGICAL FEATURES OF CALABRIA

1. Limestone and dolostone
2. Metamorphic and igneous rocks
3. Clays, marls and evaporitic rocks
4. Sandstones, marly clays and limestone marls
5. Flysch and clayey formations
6. Conglomerates, sands and sandstones
7. Alluvial deposits

Almost 90% of territory is in relief, and 10% is represented by coastal and fluvial plains. The river network is mainly made of ephemeral streams which are frequently affected by flash floods.

Tectonic stress and climatic conditions deteriorated the characteristics of rocks, predisposing slopes to landsliding.
Calabria is divided in 5 provinces and in 409 municipalities. The region is frequently affected by Damaging Hydrogeological Events. Some recent cases are shown in the next slides.
MARCH 2011: REGGIO CALABRIA PROVINCE

66 municipalities hit

4 victims
NOVEMBER 2010: REGGIO AND CROTONE PROVINCES

62 municipalities hit
1 victim

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JANUARY 2009
234 municipalities hit (57%)
2 victims
JULY 2006: VIBO VALENTIA PROVINCE

18 municipalities hit

4 victims
SOME QUESTIONS ABOUT DHEs:

1. Are calabrian Damaging Hydrogeological Events a current or an ancient problem?
2. What kind of data we need to study these events?
3. How can we classify DHEs?
4. Which results have been obtained so far?
5. What is the next step?
Currently: updating of database introducing both present and historical events

2005 Creation of the Historical archive, using data coming from several Agencies
- Genio Civile (Cosenza)
- Provveditorato alle OO.PP. Calabria Settore 32
- State Archive (Cosenza)
- Civil Protection of Calabria
- Emeroteca de “La Gazzetta del Sud”

2000 Implementation of ASICal database
www.camilab.unical.it
(Dep. of Soil Defense, University of Calabria)

1999 Collection of published data
Data diffusion is realized by ODA (Osservatorio di Documentazione Ambientale), a sector of Department of Soil Defence – University of Calabria). Currently, three data-collections are available (PDF files on Google Books), and a new published book will be presented in the next weeks.
DATA AVAILABILITY ON DAMAGING PHENOMENA

According to both the increases of information sources and attention to these phenomena, data concerning the oldest epochs are less plentiful.

For these reasons, the highest number of data pertain to 1900, and to the last 10 years.

Currently, the highest number of data available concern landslides.
DATA AVAILABLE FOR XX CENTURY

As the work goes on, the number of data available increases constantly and allows us to:

A) Improve the historical series of landslides and floods
B) Increase the knowledge about DHE throughout the Centuries
CURRENT KNOWLEDGE ABOUT THE EVENTS

Events described by literature

If we analyze the period 1801-2000, the events described by literature are 10 in 200 years.

Our historical research pointed out a greater number of events even occurred in oldest epochs.

Events disclosed by our research

33 events /200 years
According to data availability, the past can be divided in two periods:

- **Pre-measurements period** (before 1900): measured climatic data are not available and data on the events (floods, drought...) can be used to infer climatic conditions.

- **Measurements period** (after 1900): climatic data are available and can be compared to historical data about the events.
# METODOLOGICAL APPROACH: Measurement period

<table>
<thead>
<tr>
<th>DATA COLLECTION</th>
<th>DAMAGE DATA</th>
<th>RAINFALL DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATA ELABORATION</td>
<td>INDIVIDUATION OF DHEs</td>
<td>ANALYSIS OF TRIGGERING RAINFALL</td>
</tr>
<tr>
<td>RESULTS</td>
<td>CHARACTERISATION OF DHEs (rainfall/damage)</td>
<td>FOR DAMAGE-PREVENTION PURPOSES</td>
</tr>
</tbody>
</table>
CLASSIFICATION OF THE EVENTS: REGIONAL SCALE

We classified regional events basing on:

• $N_{gg}$: duration (days)
• $F$: Number of landslides (as % of the total of phenomena)
• $P$: Floods (as %...)
• $A$: Urban flooding (as %...)
• $IAD$: index expressing % of regional area affected
• $ID$: Damage Index
  $(Vi \times Li)$  $V$: relative value of damaged elements;  $L$: damage level
• $V$: number of victims
• $Tr$: return period of max daily rainfall

CLASSIFICATION OF THE EVENTS: REGIONAL SCALE

- At a **regional scale**, three types of events were individuated (A, B, C)
- The events of **Type C** show the severest effects,
  - They occurred between **October** and **November**
  - Affected the **south-south east sector** of Calabria
  - **Floods** are the most frequent type of damaging phenomena, and caused **77% of victims**
  - They occurred in the **first half of XX Century** (1932, 1951, 1953)
  - Return period of daily rainfall were greater than **20 years**
## Parameters of the Events of Type C

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Ngg</th>
<th>F(%)</th>
<th>P(%)</th>
<th>A(%)</th>
<th>IAD</th>
<th>ID</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>1932</td>
<td>nov</td>
<td>8</td>
<td>37</td>
<td>58</td>
<td>5</td>
<td>6</td>
<td>142</td>
<td>65</td>
</tr>
<tr>
<td>1951</td>
<td>oct</td>
<td>18</td>
<td>36</td>
<td>64</td>
<td>0</td>
<td>12.9</td>
<td>158</td>
<td>110</td>
</tr>
<tr>
<td>1953</td>
<td>oct-nov</td>
<td>24</td>
<td>28</td>
<td>64</td>
<td>8</td>
<td>27.8</td>
<td>189</td>
<td>85</td>
</tr>
</tbody>
</table>

**Ngg**: duration (d)  
**F**: landslides (%)  
**P**: floods (%)  
**A**: urban flooding (%)  
**IAD**: % of regional area affected  
**ID**: damage index \((V_i \times L_i)\);  
**V**: number of victims

### Regional distribution of return period of maximum daily rainfall (T)

#### Type C

- **T<2**
- **2<T<10**
- **10<T<20**
- **T>20**
- **No rain**
CLASSIFICATION OF THE EVENTS: LOCAL SCALE

According to the local geomorphological and climatic framework, in each regional sector the events can develop in a different way. For example, in **Alto Jonio** sector, **landslide damage** prevails on flood damage, because flood prone areas are quite free of vulnerable elements while landslides affect both villages and roads.
<table>
<thead>
<tr>
<th>Tipo</th>
<th>Damage</th>
<th>Damage index</th>
<th>Duration days</th>
<th>Period</th>
<th>T (Return period rainfall YEARS)</th>
<th>Rainfall with max T</th>
<th>Affected areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>VERY HIGH</td>
<td>72 86</td>
<td>165</td>
<td>Nov-May</td>
<td>18 57</td>
<td>Mean duration</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>HIGH</td>
<td>24 32</td>
<td>90</td>
<td>Oct-Feb</td>
<td>52 &gt;100</td>
<td>Short duration</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>MEDIUM</td>
<td>6 14</td>
<td>95</td>
<td>Nov-Apr</td>
<td>2 17</td>
<td>Long duration</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>LOW</td>
<td>3 6</td>
<td>88</td>
<td>Sep-Mar</td>
<td>&lt;5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DAMAGING LANDSLIDES IN CALABRIA (1921-2006)

Besides to the study of damaging hydrogeological events as a whole, we even studied a single type of phenomena (landslide, flood...)

We compared the historical series of landslide and rainfall data by using monthly and annual indices.
LANDSLIDES AND MONTHLY CLIMATIC VARIABILITY

We set some indices in order to easily compare the series of climatic data (rainfall, number of daily rainfall) and landslides data.

**Monthly precipitation index**

\[ IP_l(x, y) = \frac{\sum_{i=1}^{n} MP_i(x, y)}{\sum_{i=1}^{n} AMP_i(x)} \times 100 - 100 \]

- \( y \): year
- \( X \): month (1\( < x < 12 \))
- \( MP_i \): monthly rainfall at the gauge \( i \) in the month \( xy \)
- \( AMP_i \): monthly average of rainfall of the month \( x \) in the gauge \( i \).
- \( i \): 1, 2, ... \( n \)
- \( n \): number of gauges available for the month \( xy \)

**Monthly landsliding index**

\[ IL_l(x, y) = \frac{\sum_{i=1}^{n} ML_i(x, y)}{\sum_{i=1}^{n} AML_i(x)} \times 100 - 100 \]

- \( ML \): number of landslides occurred in the month \( xy \)
- \( AML_i \): monthly average of landslides in the month \( x \) in the municipality \( i \)
  - \( i = 1, 2, ... n; \quad n = number \ of \ municipalities \)

On a yearly scale, despite the rainfall and daily rainfall indices show a decreasing trend, the trend of landslides tend to increase. This can be due to:

- **Underestimation** of the number of landslides in the oldest periods
- **Amplification** of landslide damage. The increasing urbanization caused the increasing of vulnerable elements and, then, of landslide damage
Even for **FLOODS**, an increasing urbanization can cause the increasing of flood damage, as for example, in Reggio Calabria municipality. Here, floods which in the past didn’t caused damage currently can affect residential areas, as emerged from the study of old and recent floods.

166 floods/387 years

Victims: about 400

FLOOD TREND IN REGGIO CALABRIA (XVII-XXI CENTURIES)

SOME QUESTIONS/ANSWERS ABOUT DHEs:

1. Are calabrian Events a current or an ancient problem? DHEs are a persistent problem in Calabria

2. How can we classify these events? Basing on their effects (damage) and triggering factors (rainfall)

4. What kind of data we need to study DHEs? Data on damage, climate and anthropogenic landscape modifications

5. Which results have been obtained so far? We characterized both the severest type of regional events and local events for some regional sectors

5. What is the next step? The elaboration of further historical data in order to improve the characterization of the events both to the regional and local scale